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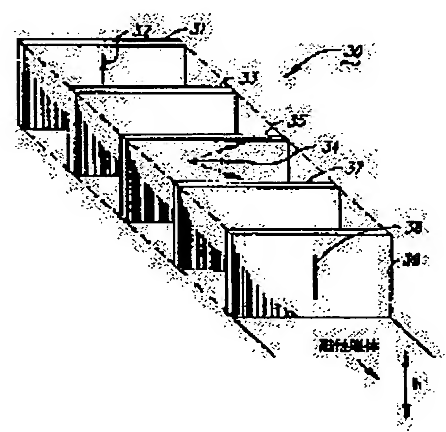
(54) DOUBLE SPIN VALVE MAGNETIC RESISTANCE SENSOR

(57)Abstract:
PURPOSE: To provide a magnetic resistance sensor in which conductive electrons scattered in any direction can be used.
CONSTITUTION: A magnetic resistance reading sensor having a multilayer double spin valve constitution is provided, based on a spin valve effect. The reading element of this sensor includes first, second, and third ferromagnetic layers 31, 35, and 39 mutually separated by anti-ferromagnetic metallic layers 33 and 37. The magnetizing directions of the first and third ferromagnetic layers 31 and 39, that is, the outside layers of this structure are fixed. The middle second ferromagnetic layer 35 is soft magnetic one, and when an applied magnetic field is absent, the magnetizing direction is vertical to the magnetizing directions of both the outside ferromagnetic layers. In one preferred embodiment, the magnetizing directions of the two outside ferromagnetic layers are mutually fixed in parallel by the switched connection with the adjacent anti-ferromagnetic layers.



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CLAIMS

[Claim(s)]
[Claim 1] It is formed on a substrate and said substrate and has the 1st, 2nd, and 3rd ferromagnetic layers separated in the layer of non-magnetic metal, respectively. Said 2nd ferromagnetic layer is arranged between said 1st ferromagnetic layer and the 3rd ferromagnetic layer. The magnetization direction is fixed in said 1st and 3rd ferromagnetic layers. The magnetization direction in said 2nd ferromagnetic layer The duplex spin bulb magnetic-reluctance sensor equipped with a laminated structure which is a parenchyma top perpendicular to the magnetization direction which the above in said 1st and 3rd ferromagnetic layers fixed when an impression field was zero.
[Claim 2] The magnetic-reluctance sensor according to claim 1 by which said each ferromagnetic layer is further characterized by having the ingredient layer of at least one addition.
[Claim 3] The magnetic-reluctance sensor according to claim 2 characterized by equipping said additional ingredient layer with at least one ferromagnetic nano layer.
[Claim 4] For said ferromagnetic layer, said nano layer is a magnetic-reluctance sensor according to claim 3 which is the layer of a different ferromagnetic material and is characterized by being arranged at the interface between said ferromagnetic layers and said non-magnetic metal layers.
[Claim 5] The magnetic-reluctance sensor according to claim 1 characterized by having a means to fix the magnetization direction in said 1st and 3rd ferromagnetic layers.
[Claim 6] The magnetic-reluctance sensor according to claim 1 by which it has the 1st hard magnetism body whorl which adjoins said 1st ferromagnetic layer, and the 2nd hard magnetism body whorl which adjoins said 3rd ferromagnetic layer, and said 1st and 2nd hard magnetism body whorls generate a bias field in said 1st and 3rd ferromagnetic layers, respectively, and are characterized by fixing the magnetization direction in said layer by it.
[Claim 7] The 1st antiferromagnetic substance layer which adjoins said 1st ferromagnetic layer and contacts this, It has the 2nd antiferromagnetic substance layer which adjoins said 3rd ferromagnetic layer and contacts this. The magnetic-reluctance sensor according to claim 1 by which said 1st and 2nd antiferromagnetic substance layers generate a bias field in said 1st and 3rd ferromagnetic layers, respectively, and are characterized by fixing the magnetization direction in said layer by it.
[Claim 8] The magnetic-reluctance sensor according to claim 1 by which thickness of said non-magnetic metal layer is characterized by being smaller than mean free path Cho of the conduction electron in a sensor.
[Claim 9] The magnetic-reluctance sensor according to claim 1 characterized by said magnetization direction in said 1st and 3rd ferromagnetic layers aligning in parallel orientation.
[Claim 10] The magnetic-reluctance sensor according to claim 1 characterized by having the coercive force from which said 1st and 3rd ferromagnetic layers differ, respectively.
[Claim 11] The magnetic storage medium which has two or more trucks for data logging, and the transductor containing a magnetic-reluctance sensor, The actuator means for being combined with said transductor and moving said transductor to the truck with which it was chosen on said magnetic storage medium, It is combined with said magnetic-reluctance sensor, and has a detection means for detecting change of the resistance. Said magnetic-reluctance sensor is formed on a substrate, and is equipped with the 1st, 2nd, and 3rd ferromagnetic layers separated in the layer of non-magnetic metal, respectively. Said 2nd ferromagnetic layer is arranged between said 1st ferromagnetic layer and the 3rd ferromagnetic layer. The magnetization direction is fixed in said 1st and 3rd ferromagnetic layers. The magnetization direction in said 2nd ferromagnetic layer The 1st antiferromagnetic substance layer which adjoins the laminated structure which is a parenchyma top perpendicular, and said 1st ferromagnetic layer to the magnetization direction which the above in said 1st and 3rd ferromagnetic layers fixed when an impression field was zero, and contacts this, It has the 2nd antiferromagnetic substance layer which adjoins said 3rd ferromagnetic layer and contacts this. The magnetic storage system by which said 1st and 2nd antiferromagnetic substance layers generate a bias field in said 1st and 3rd ferromagnetic layers, respectively, and are characterized by fixing the magnetization direction in said layer by it.
[Claim 12] The magnetic storage system according to claim 11 characterized by having an electric lead means for combining said magnetic-reluctance sensor with said detection means by which it adhered to said magnetic-reluctance sensor further on the capping layer to which it adhered on said 2nd antiferromagnetic substance layer, and said capping layer.
[Claim 13] The magnetic storage system according to claim 11 characterized by having a means to offer a vertical bias field, into the activity part of said magnetic-reluctance sensor.

[Claim 14] The magnetic storage system according to claim 11 characterized by said magnetization direction in said 1st and 2nd ferromagnetic layers aligning in parallel orientation.
[Claim 15] It is formed on a substrate and has the 1st, 2nd, and 3rd ferromagnetic layers separated in the layer of non-magnetic metal, respectively. Said 2nd ferromagnetic layer is arranged between said 1st ferromagnetic layer and the 3rd ferromagnetic layer. The magnetization direction is fixed in said 1st and 3rd ferromagnetic layers. The magnetization direction in said 2nd ferromagnetic layer It is a parenchyma top perpendicular to the magnetization direction which the above in said 1st and 3rd ferromagnetic layers fixed when an impression field was zero. Said 1st and 2nd ferromagnetic layers form the pair of the 1st ferromagnetic layer which has forward huge magnetic reluctance in the meantime, and was divided into it by the non-magnetic layer. The magnetic-reluctance sensor equipped with a laminated structure by which said 2nd and 3rd ferromagnetic layers form the pair of the 2nd ferromagnetic layer which has negative huge magnetic reluctance in the meantime, and was divided into it by the non-magnetic layer.
[Claim 16] The magnetic-reluctance sensor according to claim 15 characterized by said magnetization direction in said 1st and 3rd ferromagnetic layers aligning in the orientation of anti-parallel.
[Claim 17] The 1st antiferromagnetic substance layer which adjoins said 1st ferromagnetic layer and contacts this, It has the 2nd antiferromagnetic substance layer which adjoins said 3rd ferromagnetic layer and contacts this. The magnetic-reluctance sensor according to claim 15 by which said 1st and 2nd antiferromagnetic substance layers generate a bias field in said 1st and 3rd ferromagnetic layers, respectively, and are characterized by fixing the magnetization direction in said layer by it.
[Claim 18] The magnetic-reluctance sensor according to claim 17 characterized by having the blocking temperature from which said 1st and 2nd antiferromagnetic substance differs.
[Claim 19] Furthermore, the magnetic-reluctance sensor according to claim 15 characterized by including a means to fix the magnetization direction in said 1st and 3rd ferromagnetic layers.
[Claim 20] The magnetic-reluctance sensor according to claim 19 by which it has the 1st hard magnetism body whorl which adjoins said 1st ferromagnetic layer, and the 2nd hard magnetism body whorl which adjoins said 3rd ferromagnetic layer, and said 1st and 2nd hard magnetism body whorls generate a bias field in said 1st and 3rd ferromagnetic layers, respectively, and are characterized by fixing the magnetization direction in said layer by it.
[Claim 21] The 1st antiferromagnetic substance layer which adjoins said 1st ferromagnetic layer and contacts this, It has the 2nd antiferromagnetic substance layer which adjoins said 3rd ferromagnetic layer and contacts this. The magnetic-reluctance sensor according to claim 15 by which said 1st and 2nd antiferromagnetic substance layers generate a bias field in said 1st and 3rd ferromagnetic layers, respectively, and are characterized by fixing the magnetization direction in said layer by it.
[Claim 22] The magnetic-reluctance sensor according to claim 15 characterized by including the ferromagnetic which has the coercive force from which said 1st and 3rd ferromagnetic layers differ, respectively.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the advanced magnetic-reluctance read sensor which provides a sensor with a fixed-bias field using multilayer duplex spin bulb structure and antiferromagnetism switched connection in more detail about the magnetometric sensor for generally reading the information signal recorded on the magnetic medium.
[0002]
[Description of the Prior Art] With the conventional technique, the magnetic reading transducer called a magnetic-reluctance (MR) sensor or a head is indicated, and it turns out that this can read data in a magnetic front face by the big linearity consistency. MR sensor detects a field signal through change of the resistance as the strength of magnetic flux, and a function of a direction sensed by the reading component. MR sensor of such a conventional technique operates based on the anisotropy magnetic-reluctance (AMR) effectiveness that one component of resistance of a reading component changes in proportion to the square (cos2) of the cosine of the include angle between the magnetization direction and the direction of perception current which flows the inside of a component. More detailed explanation of the AMR effectiveness is paper"Memor(ies), such as D.A Thompson (Thompson), Storage, and and Related Applications"IEEE. It has appeared in Trans.Mag.MAG-11 and p.1039 (1975).
[0003] Furthermore, the more remarkable magneto-resistive effect returned to spin dependency dispersion by the layer interface to which change of resistance of a laminating magnetometric sensor accompanies spin dependency transmission of the conduction electron between the magnetic layers through a non-magnetic layer and it is indicated recently. This magneto-resistive effect is called by various names, such as the "huge magnetic-reluctance" effectiveness and the "spin bulb" effectiveness. Sensibility is improved and such a magnetic-reluctance sensor has a large change of resistance rather than it is made of the suitable ingredient and is observed by the sensor using the AMR effectiveness. By this kind of MR sensor, the flat-surface internal resistance between one pair of ferromagnetic layers separated by the non-magnetic layer changes in proportion to the cosine (cos) of the include angle between the magnetization directions of two layers.
[0004] The laminating magnetism structure of bringing high MR hardening produced by anti-parallel alignment of the magnetization in a magnetic layer to U.S. Pat. No. 4949039 is indicated. Although ferromagnetic transition metals and a ferromagnetic alloy are mentioned in the above-mentioned specification as a possible ingredient used by the laminated structure, the desirable ingredient superior to that of MR signal amplitude is not shown. Obtaining anti-[from which antiferromagnetism die change association was anti-used further and the layer of an adjoining ferromagnetic was separated in the thin internal layer of chromium (Cr) or an yttrium (Y)] parallel alignment is indicated by this specification.
[0005] To the United States patent application 07th of the coincidence connection for which it applied on December 11, 1990 and which was transferred to these people / No. 625343, resistance between two uncombined ferromagnetic layers changes in proportion to the cosine of the include angle between the magnetization directions of two layers, and MR sensor independent of the direction of the current passing through the inside of a sensor is indicated. When a fixed ingredient is combined, this device generates bigger magnetic reluctance than AMR, and is called huge magnetic reluctance or "spin bulb (SV)" magnetic reluctance.
[0006] To the United States patent application 07th of the coincidence connection for which it applied on August 28, 1992 and which was transferred to these people / No. 937620 Including the thin film layer of two ferromagnetics separated in the thin film layer of a non-magnetic metal ingredient, when an external impression field is zero, MR sensor based on the above-mentioned effectiveness that magnetization of one ferromagnetic layer is kept perpendicular to the ferromagnetic layer of another side by switched connection with the adjoining antiferromagnetic substance layer is indicated.
[0007]
[Problem(s) to be Solved by the Invention] By the above single spin bulb MR sensors, conduction electron is not only scattered about toward the 2nd ferromagnetic layer to which the magnetization direction is being fixed, but is scattered about also in the direction which separates from the opposite direction, i.e., the 2nd ferromagnetic layer, from the 1st ferromagnetic layer to which the magnetization direction is not being fixed. Since what is contributed to a magneto-resistive effect is only conduction electron scattered about between two ferromagnetic layers, the conduction electron scattered on an opposite direction will become useless. Therefore, the purpose of this invention is to offer MR sensor which can also use the conduction electron scattered on which direction.

[0008]
[Means for Solving the Problem] According to the principle of this invention, the magnetic-reluctance (MR) reading sensor which has multilayer duplex spin bulb structure brings about big MR response by the low impression field. This MR structure is formed on a suitable substrate, and contains the laminated structure equipped with the 1st, 2nd, and 3rd ferromagnetic thin film layers separated in the thin film layer of a non-magnetic metal ingredient. As for the 1st and 3rd ferromagnetic layer, i.e., the layer of the outside of structure, the magnetization direction is fixed, the 2nd middle layer of structure is soft magnetism, and the magnetization direction is a parenchyma top perpendicular to the magnetization direction of two outside ferromagnetic layers. "Pin attachment" [the magnetization direction of the 1st and 3rd ferromagnetic layers] [with some approaches containing the hard bias or exchange bias by the adjoining antiferromagnetic substance layer known for this technical field] [be / it / that is, / fixable and]
[0009] In the desirable example, as for two outside ferromagnetic layers, the magnetization direction is being mutually fixed by anti-parallel, therefore each fixed bed carries out the work holding the magnetic flux of the fixed bed of another side. The magnetization direction of the 2nd middle ferromagnetic layer can be freely rotated by the impression field. The electric resistance of each set of a ferromagnetic layer, i.e., the 1st layer, the 2nd layer and the 2nd layer, and the 3rd layer changes as a function of the cosine of the include angle between the magnetization directions of the two ferromagnetic layers of a pair of. When suitable ingredients including consideration of the resistivity of the ingredient as a function of conduction electron spin are chosen, effectiveness becomes addition-like between two layer pairs and the magnetization direction of a middle free layer rotates in the direction almost parallel to the magnetization direction of the 3rd outside fixed bed from a direction almost parallel to the magnetization direction of the 1st outside fixed bed, MR sensor by which resistance of a sensor changes from the minimum value to maximum can be manufactured. Perception current is supplied to MR sensor from a current source, and MR sensor generates the voltage drop which is proportional to fluctuation of resistance of MR sensor by rotation of the magnetization direction in the inside of a middle ferromagnetic free layer as a function of the impression external magnetic field sensed among the both ends of a reading component.
[0010] In the 2nd desirable example of this invention, the magnetization direction in two outside ferromagnetic layers is parallel, and a multilayer spin bulb sensor perpendicular to the magnetization direction in a middle ferromagnetic free layer is both offered.
[0011]
[Example] Probably, this invention will be clear although it is described as what is carried out in a magnetic-disk storage system as shown in drawing 1 . [applicable to other magnetic-recording systems, such as a magnetic tape record system, for example] At least one pivotable magnetic disk 12 is supported on a spindle 14, and rotates with the disk drive motor 18. The magnetic-recording medium on each disk takes the form of the annular pattern of this cardiac data track (not shown) of a disk 12.
[0012] At least one slider 13 is positioned on a disk 12, and each slider 13 supports one or more R/W converters 21 (usually called the read-write head). When a disk rotates, a slider 13 moves the disk front-face 22 top to radial in and abroad, and can access a head 21 by it at various parts of the disk with which desired data are recorded. Each slider 13 is attached in an actuator arm 19 by the suspension 15. A suspension 15 induces few spring force and a slider 13 is forced on the disk front face 22 by it. Each actuator arm 19 is attached in the actuator means 27. An actuator means is good at a voice coil motor (VCM), as shown in drawing 1 . VCM is controlled by the motor current signal by which the direction and rate of movement of a coil are supplied from a control unit including a movable coil within a fixed field system.
[0013] By working [of a disk memory system], and rotation of a disk 12, air bearing occurs between a slider 13 and the disk front face 22, and this applies the upward force to a slider. In this way, few spring force of a suspension 15 is negated and, as for air bearing, only small, almost fixed spacing raises a slider 13 up from a working disk front face.
[0014] Various components of a disk memory system are controlled by the control signal generated with the control units 29, such as working, an access-control signal, and an internal clock signal. Usually, a control unit 29 contains for example, a logic control circuit, a storage means, and a microprocessor. A control unit 29 generates the control signal for controlling various system behavior, such as a drive motor control signal on a line 23, and a head location / seeking control signal on a line 28. In order that the control signal on a line 28 may move the the best for the data track of the request on the related disk 12 and may align the selected slider 13, it offers a desired current profile. A reading signal and a write-in signal communicate between the read-write heads 21 by the record channel 25.
[0015] Illustration of drawing 1 which accompanies the above-mentioned description of a typical magnetic-disk storage system and it is only a thing for instantiation. It will be in ** that a disk memory system can include many disks and actuators, and each actuator can support some sliders.
[0016] Next, when drawing 2 is referred to, the desirable example of the MR sensor 30 by the principle of this invention contains the 1st ferromagnetic thin film layer 31, the 1st non-magnetic metal thin film layer 33, the 2nd ferromagnetic thin film layer 35, the 2nd non-magnetic metal thin film layer 37, and the 3rd ferromagnetic thin film layer 39. The magnetization direction of two outside ferromagnetic layers 31 and 39 makes the include angle of about 90 degrees to the magnetization direction of the middle ferromagnetic layer 35, when there is no external impression field which is parallel, i.e., the same direction, and is shown by arrow heads 32, 34, and 38, respectively mutually. Pin fixing [that is,] and attachment [the magnetization direction of the 1st and 3rd ferromagnetic outside

layers 31 and 39] furthermore in the desirable direction shown by arrow heads 32 and 38 That is, although the magnetization direction of the outside ferromagnetic layers 31 and 39 is being fixed, as the arrow head 34 of the broken line on a layer 35 shows to drawing 2 , the magnetization direction of the middle ferromagnetic layer 35 answers an external (it is (like field h shown in drawing 2)) impression field, and is rotated freely.

[0017] According to this desirable example of this invention, the ferromagnetic layers 31, 35, and 39 can be manufactured from those alloys, such as the suitable magnetic substance, such as cobalt (Co), iron (Fe), and nickel (nickel), and ferronickel (NiFe), nickel cobalt (NiCo), and iron cobalt (FeCo). The non-magnetic metal spacer layers 33 and 37 contain other suitable noble metals, such as copper (Cu) or silver (Ag), and gold (Au), or the alloy of those. MR sensor based on the spin bulb effectiveness that the reading component of a sensor contains the laminated structure of a ferromagnetic / non-magnetic material / ferromagnetic is indicated by the above-mentioned United States patent application 07th / No. 625343 at the detail, and builds this specification into this specification by citation. Exchange bias can be applied to the outside fixed ferromagnetic layers 31 and 39 by the layer (shown in drawing 9) of the antiferromagnetic substance, such as for example, adjoining iron manganese (FeMn). MR sensor based on the spin bulb effectiveness that a fixed ferromagnetic layer receives exchange bias by the adjoining antiferromagnetic substance layer is indicated by the above-mentioned United States patent application 07th / No. 937620 at the detail, and builds this specification into this specification by citation. The ingredient which uses the adjoining hard magnetism layer as an exception method, or has coercive force high enough in the outside fixed beds 31 and 39 can be used, and the magnetization direction of the fixed ferromagnetic layers 31 and 39 can also be fixed.

[0018] The structures of the single spin bulb MR sensor of a conventional type which is indicated by many above-mentioned patent application are free FM/NM / fixed FM/AFM fundamentally. However, free FM and Immobilization FM are the ferromagnetic layers separated by the non-magnetic layer NM. The magnetization direction of a fixed FM layer is fixed to the field of a certain amount of magnitude by the switched connection bias field brought about by the antiferromagnetic substance layer AFM. The conduction electron which moves to other FM layers is scattered about according to that spin from FM layer which has passed along NM layer, and the magneto-resistive effect of this sensor is based on resistance of a sensor increasing, when the magnetization directions in adjoining FM layer differ. It is the function of the cosine of the include angle between the magnetization directions in FM layer, change of this resistance is min when the magnetization directions are parallel, i.e., the same direction, and when the magnetization directions in a layer are anti-parallel, i.e., hard flow, it serves as max.

[0019] However, with the above-mentioned single spin bulb structure, conduction electron is not only scattered about toward a fixed FM layer from a free FM layer, but is scattered about also in the direction which separates from a fixed FM layer to hard flow. Therefore, only the part scattered about between two FM layers among conduction electron contributes to the magneto-resistive effect of a sensor.

[0020] The structure mentioned above about drawing 2 contains the "duplex" spin bulb by which spin bulb structure is a duplex in the symmetry form about the free FM layer. The structures of a duplex spin bulb are AFM1/the fixed FM1/NM1/free FM/NM2/immobilization FM2/AFM2, and bring about two pairs of FM layers separated in NM layer. By this, use of the conduction electron scattered on both directions from a middle free FM layer is attained. The direction of the magnetization in two outside immobilization FM is fixed by the antiferromagnetic substance layers AFM1 and AFM2 which adjoin, respectively, and the magnetization direction in a free FM layer answers an impression field, and can be rotated freely.

[0021] Next, reference of drawing 3 shows the end view of the drawing 2 and the duplex spin bulb sensor described about 9 and 10 by which the ferromagnetic layers FM1, FM2, and FM3 contain two or more ferromagnetic layers, respectively. As mentioned above, a duplex spin bulb sensor includes an FM1/S1/FM2/S2/FM triad. In this example, the 1st ferromagnetic layer FM 1 is called the layer 311 of the 1st ferromagnetic, such as NiFe, and a "nano layer", for example, contains the layer 313 of the 2nd ferromagnetic, such as Co. The interface of the 1st ferromagnetic layer FM 1 and the 1st spacer layer 371 adheres to the nano layer 313 of the 2nd ferromagnetic. Therefore, the 1st ferromagnetic layer forms the bilayers 311 and 313 of two sorts of different ferromagnetics. Similarly, as for the 3rd ferromagnetic layer FM 3, the nano layer 303 is formed in the interface of the 3rd ferromagnetic layer FM 3 and the 2nd spacer layer 331 including the bilayers 301 and 303 of two sorts of different ferromagnetics. Since the 2nd middle ferromagnetic layer FM 2 forms an interface with both spacer layers 331 and 371, it formed for example, contains three layers with the nano layers 309 and 307 of the 2nd ferromagnetic, such as Co, in the interface of the ferromagnetic layer 305 of centers, such as NiFe, and the spacer layers 371 and 331 of respectively contiguity, for example. The range of the thickness of a nano layer is 0.5-20A. As an exception method, a nano layer can also be formed in the interior of a ferromagnetic layer from the interface of a ferromagnetic layer and a spacer layer in the place of distance X. When forming a nano layer in the interior of a ferromagnetic layer, the ingredient of a nano layer can be used as non-magnetic materials, such as Cr, and a ferromagnetic. It applies on August 26, 1991 and the magnetic-reluctance sensor which used the above-mentioned nano layer is indicated by the United States patent application 07th of the coincidence connection transferred to these people / No. 750157 at the detail. The indication is included in this specification by citation.

[0022] Next, reference of drawing 4 and 5 indicates the magnetic-reluctance properties of the duplex spin bulb MR sensor by this invention to be the magnetic-reluctance curve 36 of the single spin bulb MR sensor of a conventional type, and a hysteresis curve 46, respectively for the comparison. As shown in drawing 4 , the spin bulb sensor of the class indicated by the above-mentioned United States patent application 07th / No. 937620 Adhere on (Silicon Si) substrate and it has the structure of Si/50Ta/75NiFe/22.5Cu/50NiFe/110FeMn/50Ta. Although the figure in an

upper type shows the thickness of an Angstrom unit and two tantalum (Ta) layers function as a buffer coat and a capping layer, respectively, 4% of maximum reluctivity **R/R is brought about. The thickness of each class is optimized so that the highest magnetic-reluctance value acquired with many ingredients in this structure may be brought about.

[0023] On the other hand, as shown in drawing 5 , it adheres to the example with a desirable duplex spin bulb on Si substrate, it has the structure of Si/50Ta/20NiFe/110FeMn/60NiFe/25Cu/100NiFe/25Cu/60NiFe/110FeMn/50Ta, and brings about 5.5% of reluctivity higher 35% than single spin bulb structure. The 1st NiFe layer in the above-mentioned duplex spin bulb structure offers the seed layer used in order to acquire the crystal structure required to bring about the antiferromagnetic substance FeMn. It has sufficient high resistivity to suppress current branching to the minimum, and if it is the ingredient into which FeMn of an antiferromagnetism form is grown up, it is suitable for using anything as a seed layer.

[0024] Next, if drawing 6 , and 7 and 8 are referred to, the duplex spin bulb MR sensor by which the magnetization direction in an outside fixed ferromagnetic layer is mutually maintained by anti-parallel, i.e., hard flow, can be designed. Furthermore, **R / R value of the sensor of a high value are generable by choosing the ingredient of each class appropriately using the spin dependency magnetic reluctance of forward [which is called huge magnetic reluctance (GMR)] and negative both. As shown in drawing 6 , both spin-up resistance (rhoup) of a ferromagnetic layer and spin down resistance (rhodown) fill related rhoup>rhodown or rhoup<rhodown including two ferromagnetic layers FM1 and FM2 from which the single spin bulb structure of having GMR of a forward sensor was separated by the non-magnetic layer NM. With this structure, resistance serves as min, when the magnetization direction of the layers FM1 and FM2 shown by the arrow head 50 is parallel, and when the magnetization directions of layers FM1 and FM2 are anti-parallel, it serves as max. As shown in drawing 7 , the single spin bulb structure of having negative GMR has two ferromagnetic layers separated by the non-magnetic layer, and is rhoup<rhodown in rhoup>rhodown and the 2nd ferromagnetic layer FM 2 in the 1st ferromagnetic layer FM 1. With this structure, resistance serves as min, when magnetization aligns at anti-parallel, as an arrow head 60 shows, and when magnetization aligns in parallel, it serves as max.

[0025] For example, drawing 8 shows three ferromagnetic layers by this invention. Among layers FM1 and FM2, GMR is forward, and when those magnetization shown by arrow heads 71 and 73 aligns in parallel, it produces the minimum resistance. On the other hand, among layers FM2 and FM3, GMR is negative, and when those magnetization shown by arrow heads 73 and 75 aligns at anti-parallel, it produces the minimum resistance. Since it is fixed to hard flow (arrow heads 71 and 75), when magnetization of the free layer FM 2 shown by the arrow head 73 aligns as effectiveness of the net of this structure at magnetization and parallel of the fixed bed FM 3 shown by the arrow head 75, resistance becomes max, and the magnetization direction of layers FM1 and FM3 becomes min when magnetization of the free layer FM 2 aligns at magnetization and parallel of the fixed bed FM 1 shown by the arrow head 71. Furthermore, since magnetization of FM1 and FM3 of the two fixed beds aligns to hard flow, each class carries out the work holding the magnetic flux of the layer of another side, and the demagnetization effectiveness of the fixed bed decreases by it.

[0026] Next, when drawing 9 is also referred to, another desirable example of the MR sensor 40 by the principle of this invention contains the 1st antiferromagnetic substance thin film layer 51, the 1st ferromagnetic thin film layer 41, the 1st non-magnetic metal thin film layer 43, the 2nd ferromagnetic thin film layer 45, the 2nd non-magnetic material thin film layer 47, the 3rd ferromagnetic thin film layer 49, and the 2nd antiferromagnetic substance thin film layer 53. Two antiferromagnetic substance layers 51 and 53 bring about a bias field into the adjoining ferromagnetic layer 41 and 49 by well-known switched connection by this technical field, respectively. The magnetization directions of two outside ferromagnetic layers 41 and 49 shown by arrow heads 42 and 48, respectively are anti-parallel, i.e., hard flow, mutually, and when there is no external impression field, they have the include angle of about 90 degrees to the magnetization direction of the middle ferromagnetic layer 45 shown by the arrow head 44. Furthermore, the magnetization direction of the 1st and 3rd outside ferromagnetic layers 41 and 49 is being fixed in the desirable direction shown by arrow heads 42 and 48 by the exchange bias of the antiferromagnetic substance layers 51 and 53, respectively.

[0027] As for the exchange bias layers 51 and 53, in this desirable example, it is desirable that FeMn and nickel manganese (NiMn) are included, respectively, including the different antiferromagnetic substance. Blocking temperature differs, therefore these two antiferromagnetic substance can set up independently the direction of exchange bias of each antiferromagnetic substance layers 51 and 53 mutually. For example, in FeMn and NiMn, the blocking temperature of FeMn is about 220 degrees C, and the blocking temperature of NiMn is much higher than it. Therefore, the direction of exchange bias of a NiMn layer is first set up at comparatively high temperature, for example, about 260 degrees C, and subsequently, the direction of exchange bias of a FeMn layer is lower than it, and it is set up at temperature with whether high it is small, for example, about 230 degrees C, rather than the blocking temperature of FeMn. As discussed above, a seed layer is used, and the antiferromagnetic substance layers 51 and 53 can have desired structure. In order to offer the sensor which produces the value of high magnetic reluctance, the ingredient of the ferromagnetic layers 41, 45, and 49 is chosen so that both forward and a negative GMR layer pair can be used. As drawing 7 was described previously, between the 1st ferromagnetic layer 41 and the 2nd ferromagnetic layer 45, GMR serves as forward, and between the 2nd ferromagnetic layer 45 and the 3rd ferromagnetic layer 49, an ingredient is chosen so that GMR may become negative. The dilution alloy which contains vanadium (V) or chromium (Cr) in nickel or Fe substrate brings about the ferromagnetic used as rhoup>rhodown, and Fe or Co in nickel substrate brings about the ferromagnetic used as rhoup<rhodown. Spin dependency resistance of

Fe or Co diluted with aluminum (aluminum), iridium (Ir), or manganese is also known. The nonmagnetic spacer layers 43 and 47 can use Cu, Au, Ag, etc. as suitable non-magnetic metal. As for the thickness of the antiferromagnetic substance layers 51 and 53, it is desirable that they are 50 thru/or 200A.

[0028] Next, reference of drawing 10 shows still more nearly another example of the duplex spin bulb MR sensor by this invention. Before adhering the 1st antiferromagnetism exchange bias layer 59, the suitable lower layers 57, such as Ta, Ru, and CrV, are adhered on a substrate 55. The purpose of a lower layer 57 is optimizing the texture of many consecutiveness layers, grain size, and a gestalt. A gestalt may be very important for acquiring the big MR effectiveness property of single spin bulb structure. It is because it will become possible to use the very thin non-magnetic metal spacer layers 63 and 65 among the ferromagnetic layers 61, 65, and 69 if it does so. A lower layer must have high resistivity again, in order to suppress the current branching effectiveness to the minimum. When the substrate 55 is made of the ingredient of resistivity high enough and has a front face flat enough and suitable crystallographic structure, a lower layer 57 can be omitted. If FeMn, NiMn, etc. are the suitable antiferromagnetic substance, they can be used for the exchange bias layer 59 anything. If FeMn (60/40 % of the weight) is used, when specifically adhering a FeMn antiferromagnetic substance layer first, the joint field between two consecutive ferromagnetic layers decreases. When it cannot adhere directly so that the ingredient used for the 1st antiferromagnetic substance layer 59 may have the suitable crystal structure, a seed layer (not shown) may also be needed. For example, in order to obtain FeMn of an antiferromagnetism form when using FeMn for an exchange bias layer as discussed above, the seed layer of NiFe or AuCu is preferably desirable.

[0029] The 1st ferromagnetic thin film layer 61, the 1st non-magnetic metal thin film layer 63, the 2nd ferromagnetic thin film layer 65, the 2nd non-magnetic metal thin film layer 67, the 3rd ferromagnetic thin film layer 69, and the 2nd antiferromagnetic substance thin film exchange bias layer 71 are adhered on a lower layer 57. The magnetization direction of the 1st and 3rd ferromagnetic layers 61 and 69 is parallel to mutual, and when there is no impression field, the include angle of about 90 degrees is made to the magnetization direction of the 2nd middle ferromagnetic layer 65. As mentioned above, a location is fixed by the bias field which generated the magnetization direction of the 1st and 3rd ferromagnetic layers 61 and 69 by switched connection. The outside ferromagnetic layers 61 and 69 are fixable by using an adjoining hard magnetism layer, or using the comparatively high ingredient of coercive force for an outside ferromagnetic layer as an exception method, and setting up the magnetization direction during manufacture. When it is anti-parallel, in order for the magnetization directions of the outside ferromagnetic layers 61 and 69 to differ, for example, for the magnetization direction of one layer to be able to set up independently of the layer of another side, the coercive force of each class must differ.

[0030] The suitable magnetic substance, such as Co, Fe, and nickel, or NiFe, NiCo, FeCo, etc. can manufacture the ferromagnetic layers 61, 65, and 69 from those alloys. The thickness of the ferromagnetic layers 61, 65, and 69 can be chosen in about 5-150A.

[0031] As for the nonmagnetic spacer layers 63 and 67, it is desirable that it is the metal of high conductivity. Noble metals, such as Au, Ag, and Cu, give big MR response, Pt and Pd give small MR reaction, and Cr and Ta show very small MR response. The thickness of the nonmagnetic spacer layers 63 and 67 is smaller than the mean free path of the conduction electron in a sensor, and it is desirable to choose in about 10-40A.

[0032] Next, on MR sensor, the capping layers 73 of high electrical resistance materials, such as Ta and a zirconium (Zr), are adhered. Lead wire 76 is formed and a circuit path is formed between MR sensor, a current source 77, and the sensing means 79. Furthermore, in order to suppress a Barkhausen noise to the minimum, it is desirable to offer a vertical bias field parallel to the lengthwise direction of the magnetic layer in a sensor. If the layer 75 of a suitable hard magnetism object is adhered on the edge field of a sensor as everyone knows in this technical field, a vertical bias field will be formed in the active region 78 of the center of a sensor. A vertical bias field can also be formed by the switched connection by the antiferromagnetic substance layer which contacted a ferromagnetic layer and directly and was made to form on the edge field of a sensor as an exception method.

[0033]

[Effect of the Invention] According to this invention, the conduction electron scattered on both directions towards an outside ferromagnetic layer from a middle ferromagnetic layer can be used.

[Translation done.]

DESCRIPTION OF DRAWINGS

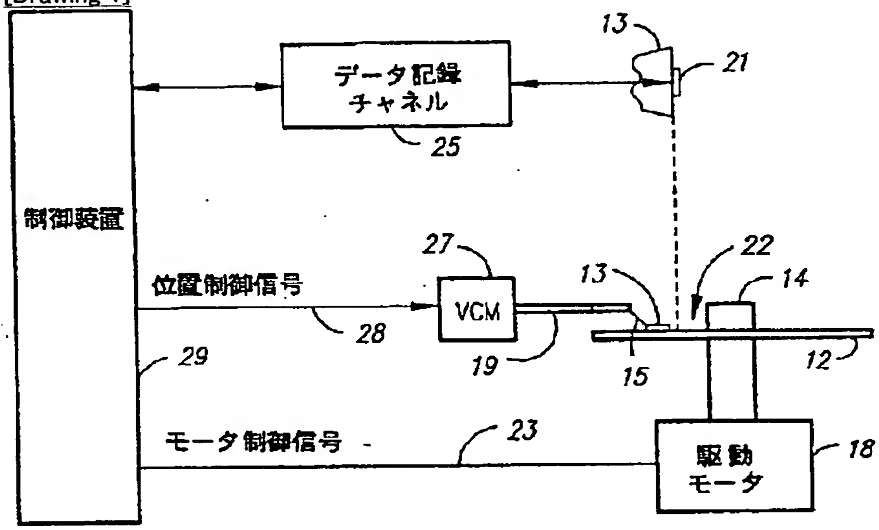
[Brief Description of the Drawings]
[Drawing 1] It is the block diagram with which the magnetic-disk storage system which carries out this invention was simplified.
[Drawing 2] It is the decomposition perspective drawing of the desirable example of the magnetic-reluctance sensor by the principle of this invention.
[Drawing 3] It is the end view of other desirable examples of the magnetic-reluctance sensor by the principle of this invention.
[Drawing 4] It is the graph which shows the hysteresis curve of the spin bulb MR sensor structure of the conventional technique, and a magnetic-reluctance response.
[Drawing 5] It is the graph which shows the magnetic-reluctance response of MR sensor shown in drawing 2 .
[Drawing 6] It is the schematic diagram showing the spin bulb structure of having forward huge magnetic reluctance.

[Drawing 7] It is the schematic diagram showing the spin bulb structure of having negative huge magnetic reluctance.
[Drawing 8] It is the schematic diagram of the duplex spin bulb using the forward and negative huge magnetic reluctance by the principle of this invention.
[Drawing 9] It is the decomposition perspective drawing of another desirable example of the magnetic-reluctance sensor by the principle of this invention.
[Drawing 10] It is the end view of another example of the magnetic-reluctance sensor built according to this invention.

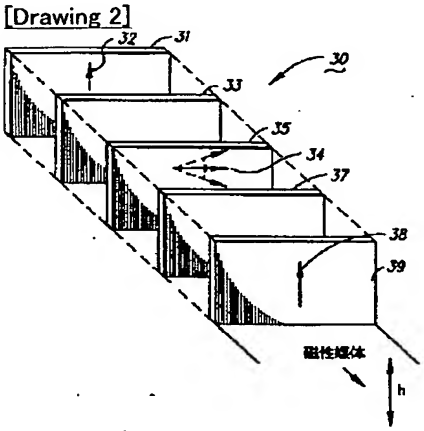
[Translation done.]

DRAWINGS

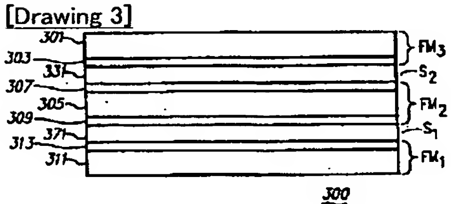
[Drawing 1]



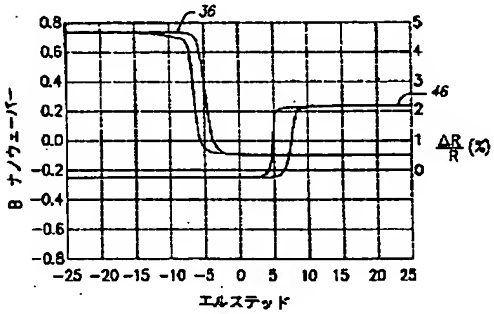
[Drawing 2]



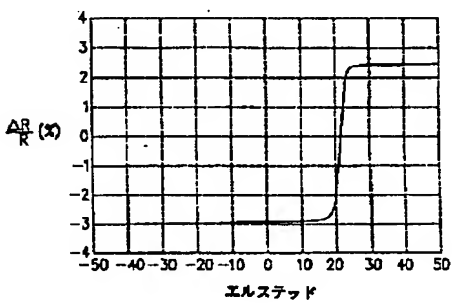
[Drawing 3]



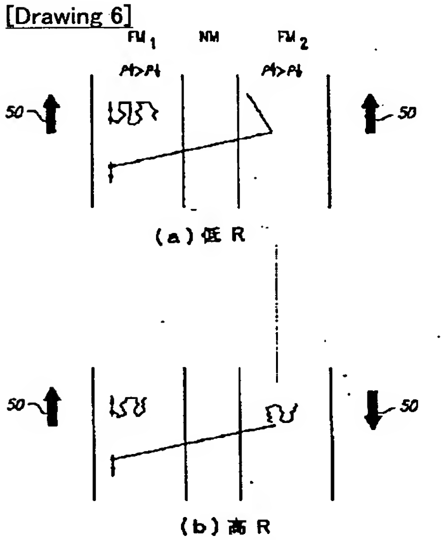
[Drawing 4]



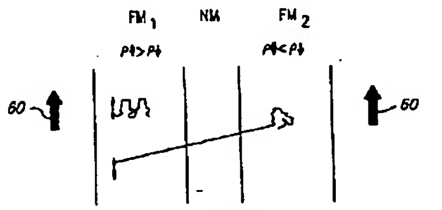
[Drawing 5]



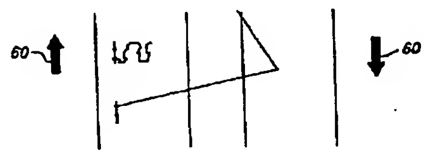
[Drawing 6]



[Drawing 7]

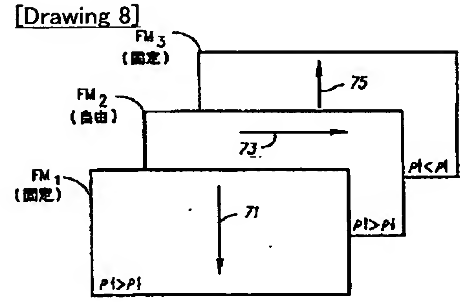


(b) 高 R

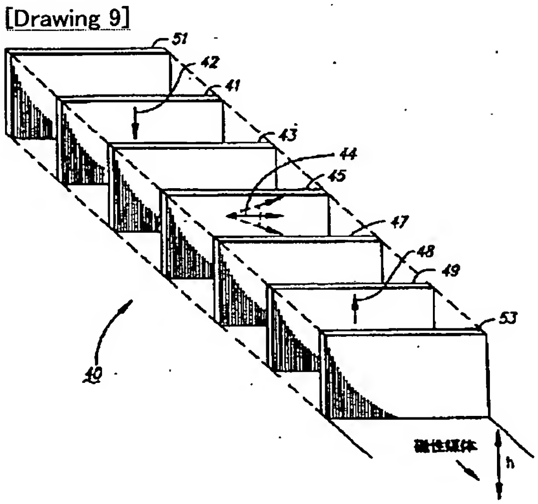


(a) 低 R

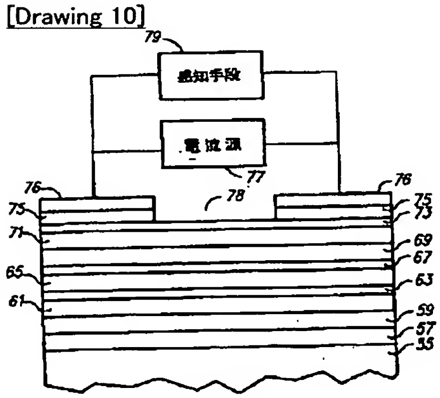
[Drawing 8]



[Drawing 9]



[Drawing 10]



[Translation done.]